

The East-Asian VLBI Network

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Abstract.

The East-Asian VLBI Network (EAVN) is the international VLBI facility in East Asia and is conducted in collaboration with China, Japan, and Korea. The EAVN consists of VLBI arrays operated in each East Asian country, containing 21 radio telescopes and three correlators. The EAVN will be mainly operated at 6.7 (C-band), 8 (X-band), 22 (K-band), and 43 GHz (Q-band), although the EAVN has an ability to conduct observations at 1.6 – 129 GHz. We have conducted fringe test observations eight times to date at 8 and 22 GHz and fringes have been successfully detected at both frequencies. We have also conducted science commissioning observations of 6.7 GHz methanol masers in massive star-forming regions. The EAVN will be operational from the second half of 2017, providing complementary results with the FAST on AGNs, massive star-forming regions, and evolved stars with high angular resolution at cm- to mm-wavelengths.

1. Introduction

A new VLBI array in East Asia, the East-Asian VLBI Network (EAVN), is being planned under the collaboration of the East Asia Core Observatory Association (EA-COA). VLBI facilities are developing and operating in each East Asian country, the Chinese VLBI Network (CVN; Li et al. 2008) in China, the Korean VLBI Network (KVN; Lee et al. 2014) in Korea, the Japanese VLBI Network (JVN; Doi et al. 2006) and VLBI Exploration of Radio Astrometry (VERA; Kobayashi et al. 2003) in Japan, and various international collaboration programs, such as the KVN and VERA Array (KaVA), is ongoing by using those facilities. On the basis of this background, a small task force ‘the EAVN Tiger Team’ was organized in June 2013, consisting of 17 members from China, Japan, and Korea, to handle various issues related to EAVN, such as

promotion of VLBI test observations, clarification of the problems for future regular operation of EAVN, and so on. The work of this task force is carried out as part of activities in ‘the East Asian VLBI Consortium’, which is one of working groups under the EACOA.

2. Overview of EAVN

Figure 1 shows an overall image of the EAVN, which consists of 21 potential telescopes, 5 from China, 12 from Japan, and 4 from Korea, and two correlator sites, Korea-Japan Correlation Center (KJCC) in KASI, and Shanghai Astronomical Observatory. Details of the telescopes and brief specifications of the EAVN are shown in Tables 1 and 2, respectively. In Table 1, filled symbols indicate telescopes which have participated in fringe test observations to be described in Section 3, open squares show antennas participated in VLBI observations of methanol masers in massive star-forming regions at 6.7 GHz conducted in 2010 and 2011 (Fujisawa et al. 2014), and open and filled triangles correspond to antennas constituting the KaVA, which is operational at 22 and 43 GHz (Matsumoto et al. 2014; Niinuma et al. 2014).

Figure 2 shows examples of (u, v) coverage for an EAVN observation at 22 GHz with the various declination of a source. The EAVN can sample visibilities of a wide range of baseline lengths from 20 km (JVN-Tsukuba – JVN-Kashima) to 5,000 km (CVN-Nanshan – VERA-Ogasawara), allowing us to obtain a round-shaped synthe-

Table 1. Potential EAVN Telescopes.

Name	Array	Longitude [° N]	Latitude [° E]	Diameter [m]	Observation Band			
					C	X	K	Q
Kunming	CVN	25.027	102.796	40	○	●		
Miyun	CVN	40.558	116.976	50		○		
Nanshan	CVN	40.399	116.239	26	○	●	●	
Sheshan	CVN	31.099	121.200	25	□	●	●	
Tianma	CVN	31.092	121.136	65	○	●	○	○
Gifu	JVN	35.468	136.737	11			○	
Hitachi	JVN	36.697	140.692	32	□	●	●	
Kashima	JVN	35.956	140.660	34		○	○	○
Takahagi	JVN	36.699	140.695	32			●	
Tomakomai	JVN	42.674	141.597	11			○	
Tsukuba	JVN	36.103	140.089	32		●	○	
Usuda	JVN	36.132	138.363	64	□	○		
Yamaguchi	JVN	34.216	131.557	32	□	●	○	
Iriki	VERA	31.748	130.440	20	□	●	▲	△
Ishigakijima	VERA	24.412	124.171	20	□	●	▲	△
Mizusawa	VERA	39.134	141.133	20	□	●	▲	△
Ogasawara	VERA	27.092	142.217	20	□	●	▲	△
Sejong	—	36.520	127.303	22		●		
Tamna	KVN	33.289	126.460	21			▲	△
Ulsan	KVN	35.546	129.250	21	○	●	▲	△
Yonsei	KVN	37.565	126.941	21			▲	△

Table 2. Specifications of EAVN.

Number of (potential) telescopes	21
Frequency coverage	6.7 GHz (12 stations), 8 GHz (16), 22 GHz (17), 43 GHz (9)
Angular resolution	1.5 mas (8 GHz), 0.6 mas (22 GHz), 0.7 mas (43 GHz)
7- σ Fringe detection sensitivity	1.6 mJy (8 GHz), 9.5 mJy (22 GHz) (for a continuum source, $\tau = 60$ s)
Recording rate	≥ 1 Gbps ($B = 256$ MHz)
Correlator	Korea-Japan Joint VLBI Correlator (KASI), DiFX (KASI/SHAO)

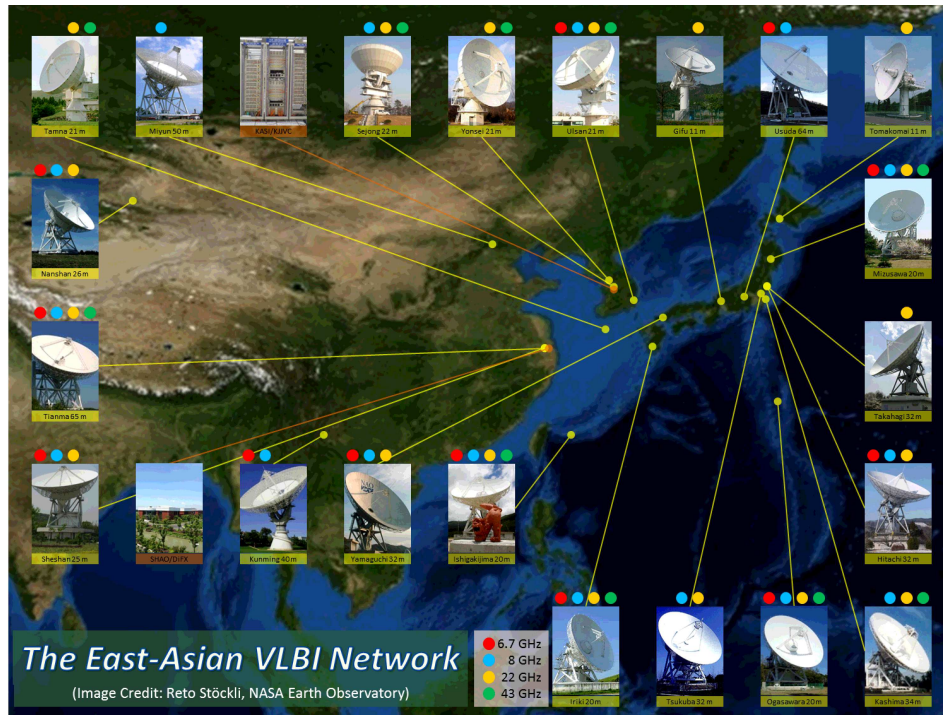


Figure 1. Location of EAVN sites. Photos of potential EAVN telescopes (yellow points) and correlator sites (brown points) are overlaid on ‘the Blue Marble’ image (image credit: NASA’s Earth Observatory).

sized beam with very low noise level thanks to a lot of large antennas, as shown in Table 1.

3. Results of Fringe Test Observations

We have carried out test observations with the EAVN eight times since 2013 at 8 and 22 GHz in order to get fringes between international baselines of the EAVN, and to clarify the problems associating with the scheduling, correlation, and data reduction.

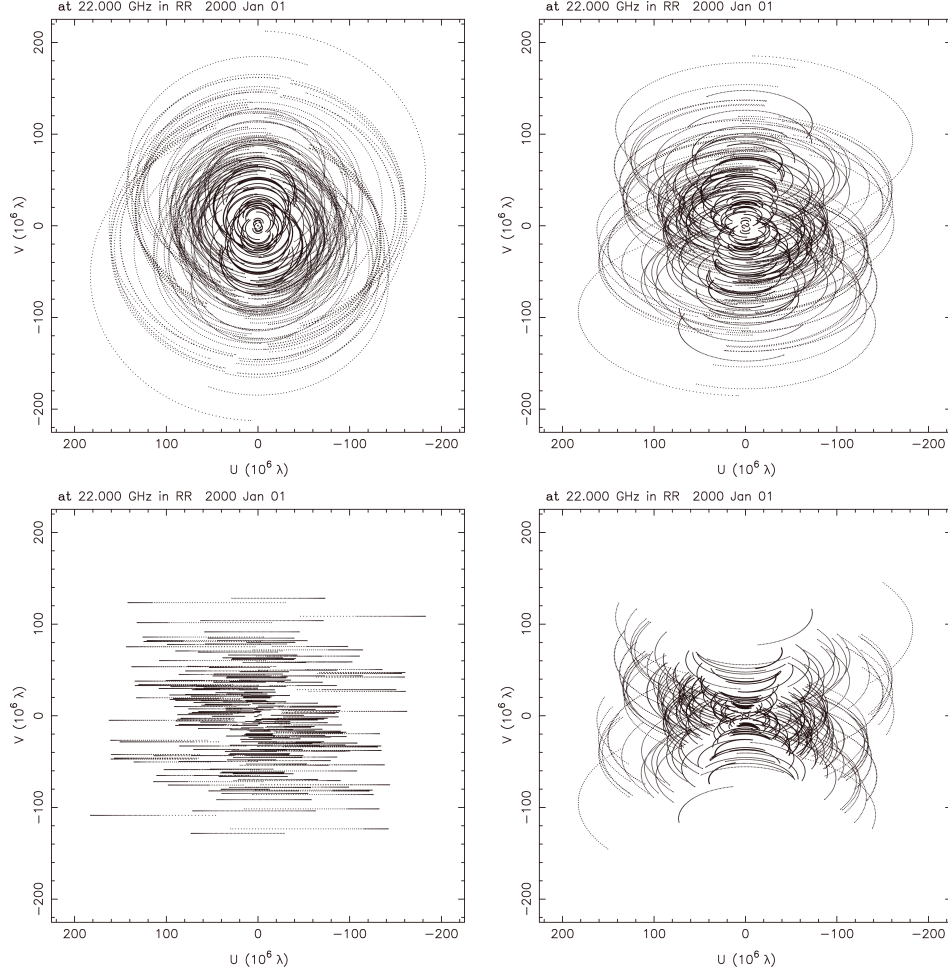


Figure 2. Examples of (u, v) coverage for an EAVN observation at 22 GHz with the source’s declination of $+60^\circ$ (top left), $+30^\circ$ (top right), 0° (bottom left), and -29° (bottom right). Total observation duration of 10 hours is assumed for all cases.

16 telescopes have participated in fringe tests one or more times at either 8 or 22 GHz, or at both frequencies (see Table 1).

Throughout those fringe tests, we could detect fringes at both frequencies. Figure 3 shows examples of fringe test results conducted on 2015 February 12 at 8 GHz. Four telescopes, Tsukuba (JVN), Ulsan (KVN), Sheshan and Kunming (CVN), participated in the observation, with a bright AGN 3C 454.3 being a target source. Fringes were successfully detected between all international baselines in China, Japan, and Korea. Although discontinuous fringe phases and amplitudes can be seen between each IF channel in the raw visibility, those are well-calibrated after fringe fitting and amplitude correction. Discontinuous fringe phases appear in the international baselines between trans-CVN baselines (i.e., Sheshan/Kunming – Tsukuba/Ulsan baselines), although those cannot be seen in the visibility of Sheshan – Kunming and Tsukuba – Ulsan baselines. This phenomenon is probably due to the different bit assignment in the backend system between CVN and KVN/JVN stations. This can be compensated

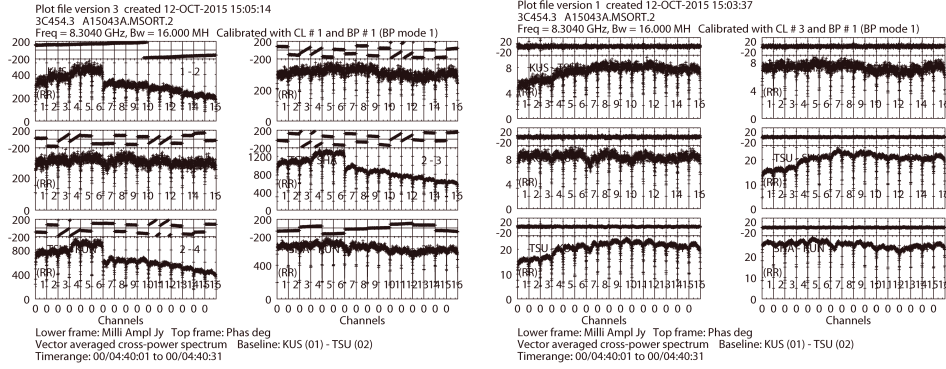


Figure 3. Results of the fringe test observation conducted on 2015 February 12 at 8 GHz. (Left) Raw visibility phases (upper) and amplitudes (lower) for each baseline. (Right) Calibrated visibility phases and amplitudes with the AIPS task FRING and ACCOR. Note that *a priori* amplitude calibration with the AIPS task APCAL is not applied.

by the correlator and good fringe phases and amplitudes can be obtained after fringe fitting and amplitude calibration, as shown in Figure 3.

4. Future Plan and Synergy with the FAST

4.1. Future Plan of the EAVN Test Observation

On the basis of the results obtained with eight-time fringe tests, we will start imaging test observations with the EAVN from the end of 2015. We conduct test observations at 8 and 22 GHz as a first step, whereas we will also begin both fringe tests and imaging observations from 2016 at 6.7 and 43 GHz, both of which are common observing frequencies and science commissioning observations have already been conducted with part of EAVN telescopes, as mentioned in Section 1. As of this stage, we will begin to invite observing proposals for the EAVN from the second half of 2017.

4.2. Synergy and Collaboration with the FAST/Other Arrays

The FAST telescope will have a capability of the data reception system at 70 MHz – 3 GHz, while some of EAVN telescopes have receivers at 1.6 and/or 2 GHz. The minimum sensitivity for 7- σ fringe detection of a few hundred mJy will be achieved at both 1.6 and 2 GHz between the FAST and the Usuda 64 m telescope of the JVN, assuming the antenna diameter of 300 m, the aperture efficiency of 20%, and the system noise temperature of 25 K for the FAST, and the integration time of 60 seconds. The extremely high sensitivity allows us to investigate relatively weak radio sources such as low-luminosity AGNs, and to detect much more OH (mega-)maser sources in galactic and extragalactic objects.

In the Asia-Pacific region, the Long Baseline Array (LBA) in Australia has already been made regular operation, and collaborative work between the EAVN and the LBA has been made as a part of the framework in the Asia-Pacific Telescope (APT). The maximum baseline length of longer than 10,000 km can be obtained with the combined EAVN and APT array in the north-south direction. This enable us to obtain better

angular resolution and (u, v) coverage toward sources at low declination and southern sources. A new VLBI array project, the Thai VLBI Network (TVN), is also in progress in Thailand, and we are planning to pursue collaboration with both LBA and TVN in the near future,

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